MAT-92-04

Effects of Piped Median vs. Open Ditch Drainage on Stormwater Quality

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Documentation Page

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Author(s): F. Ivan Lorant - Project Manager, M.M. Dillon Limited

Date Published: March, 1992

Published by: Research and Development Branch, MTO

Contact Person: Jack Armstrong, Materials Office
(416) 235- 5254

Abstract:

The objective of the program on the effects of piped median versus open ditch drainage on stormwater quality was to prepare a literature review and to conduct a subsequent field study.

In the U.S. and Europe, a substantial amount of research has been done regarding receiving water pollution due to motor vehicle operations. Many of these studies indicate that highway runoff can represent a non-point source of pollution, which may have a significant impact on critical receiving waters. The only Canadian study identified is the soon-to-be released work conducted by the National Water Research Institute in Burlington.

According to the extensive monitoring carried out by the U.S. Federal Highway Administration, highways with traffic volume under 30 000 vehicles per day exert minimal impact on the aquatic components of the receiving streams. Also, it was found that highway runoff conveyed by overland flow in an unlined or grassed channel over a distance of at least 60 m, prior to discharging into the receiving stream, exhibited minimal downstream impacts. A detailed literature review was prepared in a separate volume (unpublished), entitled "Highway Runoff Water Quality, Literature Review" March 1990.

The second part of the project involved field monitoring to study the relative effects of grassed and impervious surface channels on highway runoff quality. Two sites were selected along Highway 401, a grassed median section near the Dorchester Swamp and a paved section over Putnam Road. Eight composite samples were collected and analyzed, however, the grassed channel width was reduced during the early part of the monitoring program by urgent, safety-related road improvement works.

When compared to the MOE water quality objectives for the protection of aquatic habitat, the copper, iron, zinc, ammonia and total phosphorus average concentrations exceeded the objectives. There was insufficient data collected at the undisturbed grassed median to determine the effects of a grassed channel on the quality of runoff.

Comments: This work adds to our knowledge base of the effects of highway stormwater runoff on receiving watercourses under Ontario conditions. A literature review, MAT-92-13, is also available.

Key Words: water quality, stormwater, highways, ditches, aquatic habitat, non-point pollution

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F. Ivan Lorant
Project Manager
M. M. Dillon Limited

Published by
The Research and Development Branch
Ontario Ministry of Transportation

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For additional copies, contact:
The Editor, Technical Publications
Room 320, Central Building
1201 Wilson Avenue
Downsview, Ontario
Canada M3M 1J8

Telephone: (416) 235-3480
Fax: (416) 235-4872

March 1992

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1/ Introduction

The following report on the effects of piped median and open ditch drainage design on stormwater quality is based on an extensive literature review (MAT-92-13) and a brief field monitoring program.

Environmental regulatory agencies have expressed concern about the quality of receiving water and the associated downstream effects, where piped and paved median drainage systems are installed on major freeways or expressways.

Environmental regulatory bodies are developing site specific programs to control and regulate the water quality of municipal and industrial drainage. The Ministry of Transportation (MTO) is currently unable to respond properly to the above concern, as there is no Ontario data base available on the subject.

The objective of the project is to prepare a literature review on the subject of stormwater quality in highway runoff, focusing on work published since 1980, and to conduct a field study for a specific MTO site, and examine the relative water quality effects of piped and grassed drainage channels.

2/ Background

Past research in the field of stormwater management concentrated on the quantity issues, specifically on the rainfall-runoff relations caused by different land use activities. Until recently, there was a lack of data and concern regarding storm water quality.

The highway system is a potential source of a wide variety of possible pollutants, as demonstrated in Table 1, to surrounding surface and subsurface waters. The effects of a highway system on the environment play an important role in the planning, design, construction and operation of a transportation system. MTO is charged with the responsibility of protecting the environment from highway pollution.

In the U.S. and Europe, a substantial amount of research has been done regarding receiving water pollution due to motor vehicle operation. Numerous studies of highway drainage indicate that highway runoff can represent a non-point source of pollution, which may have a significant impact on critical receiving waters in heavily travelled sections. Such studies were conducted during the last five to ten years in Europe, the U.S. and very recently, in Canada. The U.S. studies sponsored by the Federal Highway Administration and the soon to be released Canadian study conducted by the National Water Research Institute in Burlington, are particularly relevant in this connection, recognizing some differences between European and North American conditions.

Table 1/ Common highway runoff constituents and their primary sources

Constituent	Primary Source
Particulates	Pavement wear, vehicles, atmosphere, highway maintenance.
Nitrogen, phosphorous	Atmosphere, roadside fertilizer application.
Lead	Leaded gasoline (auto exhaust), tire wear (lead oxide filler material), lubricating oil and grease, bearing wear.
Zinc	Tire wear (filler material), motor oil (stabilizing additive), grease.
Iron	Autobody rust, steel highway structures (guardrails, etc.) moving engine parts.
Copper	Metal plating, bearing and bushing wear, moving engine parts, brake lining wear, fungicides and insecticides applied by maintenance operations.
Cadmium	Tire wear (filler material), insecticide application.
Chromium	Metal plating, moving engine parts, brake lining wear.
Nickel	Diesel fuel gasoline (exhaust) and lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving.
Manganese	Moving engine parts.
Bromide	Auto exhaust.
Cyanide	Anti-cake compound (ferric ferrocyanide, Prussian Blue or sodium ferrocyanide, Yellow Prussiate of Soda) used to keep deicing salt granular.
Sodium, Calcium	Deicing salts, grease.
Chloride	Deicing salts.
Sulphate	Roadway beds, fuel, deicing salts.
Petroleum products	Spills, leaks or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate.
Polychlorinated biphenyls, pesticides	Spraying of highway right-of-ways, background atmospheric deposition, PCB catalyst in synthetic tire.
Pathogenic bacteria (indicators)	Soil, litter, bird droppings, and trucks hauling livestock and stockyard waste.
Rubber	Tire wear.
Asbestos	Clutch and brake lining wear.

Note: *The above table was compiled from U.S. and European literature.*

Concerns about highway runoff quality are being expressed by various Ontario environmental agencies in connection with a number of parameters, including sediment, metals, petroleum hydrocarbons, and de-icing agents. A general summary of these parameters are presented below, based on a literature review undertaken as part of this study (Dillon 1990). However, there is a lack of Ontario published data on highway runoff quality. While a range of levels of some parameters in highway runoff can be established, the impact of discharges of such pollutants on the receiving waters is much more difficult to quantify. The lack of accompanying water hardness data (affecting e.g. metal toxicity) and the little known partitioning of the observed loads between the dissolved and absorbed phases limits impact analysis.

In addition, many environmental agencies are taking an end of pipe approach to control the quality of discharge.

Highway runoff transports significant quantities of **sediment** produced by abrasion of highway surfaces, de-icing abrasives and from traffic by-products. The sediment, particularly in the form of the suspended load, affects the water quality of receiving waters by reducing sunlight penetration and silting up fish spawning beds.

Highway runoff conveys quantities of **metals**, including lead, zinc, cadmium and copper. Such loads are carried typically in the absorbed form attached into the sediments, which function as the sink for much of these loads.

Highway runoff is a source of petroleum hydrocarbons. These can include the polynuclear aromatic hydrocarbons (PAHs), many of which are included in the U.S. EPA list of priority pollutants. Studies in Europe as well as those conducted in Canada by the National Water Research Institute (NWRI), indicate that PAH concentrations in unfiltered runoff samples may be high, with the majority of such loads being transported in the particulate form. The much lower dissolved loads and the possible exchange between the sediment and the water column may cause concerns in environmentally sensitive receiving waters.

De-icing Salt ions in highway runoff may be cause for concern. In winter and spring months, the chloride concentrations in runoff may reach such levels that a significant impact is created on receiving waters. Furthermore, discharges of salt may lead to density effects in the receiving waters with the accompanying problems caused by reduced mixing in the receiving water bodies. It should be also noted that road salt often contains other chemicals (e.g. cyanides in anti-caking compounds), although this is not the case in Ontario.

Other substances in highway runoff may also cause concern, but the significance of their loadings is questioned in terms of impact. They include the substances exerting **oxygen demand** and characterized by the BOD (biochemical oxygen demand) value and some forms of **nutrients**, particularly ammonia and nitrate.

In summary, there is limited data available in the literature on highway runoff composition, described for numerous water quality parameters. Such data need to be evaluated and interpreted in the context of the Ontario conditions and the knowledge gaps should be identified. It appears parameters of interest may include: sediment, toxic metals, PAHs, petroleum hydrocarbons, nutrients, substances exerting oxygen demand, and cyanides in anti-caking compounds if used in road salt. The loadings of all parameters need to be evaluated with reference to the receiving water conditions, substance speciation and bio-availability, and partitioning between solid and liquid phases.

At the time of writing, no water quality data has been released in Ontario on highway runoff. Federal Research Institutions, provincial ministries and Conservation Authorities are active in the field of stormwater management.

Past Ontario stormwater management techniques were designed mainly to control peak flows. A new set of interim guidelines was released recently by the Ministry of the Environment and Ministry of Natural Resources (Interim Stormwater Quality Guidelines, July 1991), which includes the control of stormwater quality from new urban developments. These guidelines follow the trend in detaining runoff volume, up to a pre-determined duration, for a period varying from one to three days.

Runoff from urban areas and highways was also identified by the International Joint Commission as a source of many toxic contaminants in the Great Lakes Water Quality Board report in 1985.

The Canadian Council of Resource and Environmental Ministers report (1987) found that typical levels of heavy metals in highway runoff significantly exceeded the Canadian Water Quality Guidelines for fresh-water aquatic life.

Point sources of pollutants to Ontario surface waters are coming under increasing control as a result of the MISA (Municipal Industrial Strategy for Abatement) initiative. MISA will regulate pollutant loadings and impose pre-treatment requirements for both indirect and direct dischargers. As part of this program, MISA considers the loadings arising from runoff from industrial sites.

Although non-point sources of pollutants are not addressed specifically at this time by MISA, with the exception of site runoff mentioned above, the Ontario Ministry of the Environment (MOE) is carrying out

other activities to support MISA, such as the Urban Drainage Management Program and extensions to the existing Municipal Pollution Control Program. MOE is also undertaking a major review of its traditional approach to water quality impact assessment. This will include development of ambient provincial water quality objectives (PWQO) for more toxic substances than listed in the 1984 revised version of *"Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment"*.

3/ Summary of Literature Review on Highway Runoff Water Quality

The Ministry of Transportation is committed to developing a stormwater quality management policy and as a first step, has initiated a literature review of stormwater quality, generated from highways.

The following is a summary of the literature review undertaken for this study, based on North American, United Kingdom, German and Scandinavian literature, addressing the highway runoff quality issues. The detailed review is presented in a separate volume titled *Highway Runoff Water Quality, Literature Review* (March 1990).

The material reviewed is grouped under two headings:

a) the quality of stormwater as it leaves an operating highway; and

b) the degree to which the quality of stormwater improves as it passes through a variety of paths.

Some of the individual water quality samples collected during the monitoring programs in the U.S., U.K. and continental Europe showed an elevated level of pollutants.

According to Kobriger and Geinepolos (1984) and Kerri (1985), urban highways in California do not produce large amounts of pollutant constituents during storm runoff events. Monitoring at highways, which drain between 1 and 2 hectares of completely paved areas and have six to eight lanes, produce pollutant loads in runoff water which are sufficiently low, so that costly treatment facilities are not needed to meet water quality objectives.

According to German experiments (Stotz), only 5-20% of the total pollution arising from motor vehicle traffic is discharged with the runoff. The remainder is disposed by wind, vehicular turbulence or spread onto the shoulder of the highway. No such data has been found in the U.S. literature.

Generally, highway runoff contains pollutant levels comparable to urban runoff.

The U.S. Federal Highway Administration Research Report on *Effects of Highway Runoff on Receiving Waters* (Vol. II, August 1985) concluded that for the parameters tested, rural highways with traffic volume under 30,000 vehicles per day exert minimal or no impact on the aquatic components of most receiving waters.

The U.S. Federal Highway Administration report on *Management Practices for Mitigation of Highway Storm Water Runoff Pollution* (Volume I, Guidelines, 1985) states the following conditions when highway runoff is not likely to have adverse effects on receiving waters:

1. No public water supply involved in the receiving waters.

2. The highway has less than 30,000 vehicles as the average daily traffic (ADT), or

3. The highway runoff is conveyed by overland flow in an unlined or grassed channel, at least over a distance of 60 m, prior to discharging into the receiving stream, or

4. The dilution ratio between highway runoff and receiving streamflow is at least 1 to 100.

The above list of conditions are by no means exhaustive, but it is intended to provide a screening mechanism to identify potential areas of concern.

According to the practice recommended in the above report, water quality effects on receiving waters are assessed according to the increases in concentration or loading of a particular pollutant over background conditions. The possible impacts are compared to the criteria established for water quality standards.

Unfortunately, the water quality effects from highway runoff have not been covered adequately in the literature.

A brief summary of the highway generated pollutants and their effects described in the literature are presented below. It is important to point out that the information listed below is not based on Ontario conditions. For a more detailed background data, the reader is referred to the separate volume of literature review and/or to U.S. Federal Highway Administration publication on *Effects of Highway Runoff on Receiving Waters*, 1985.

- **Dissolved Oxygen Depletion**. Generally the BOD is less than 30 mg/L, based on urban stormwater data. There is no data on BOD for highway runoff.

- **Nutrients**. Urban stormwater runoff can, in some cases, contain ammonia and nitrate levels in excess of those recommended by EPA for public health reasons. Excessive nutrients can also create accelerated growth of nuisance aquatic plants in water bodies. Such conditions have been reported for urban stormwater but not for highway runoff alone.

- **De-icing Agents**. The use of de-icing agents and their effect on receiving waters and nearby soils is well documented in the literature.

  Generally, the effects in streams and rivers were less pronounced, where dilution, especially during rain or melt conditions, managed to keep the chloride levels below the Canadian and U.S. EPA criteria of 250 mg/L. For lakes and wetlands, road salts can show high accumulation above the criteria.

- **Metals**. Highway runoff contains metals, but few field studies have shown elevated metals concentrations in the receiving water. The observed high metal content of sediments implies a rapid removal of metals by sedimentation.

  In some cases, metal concentration in highway runoff sediments can be an order of magnitude higher than the background sediments and may cause an impact that is currently unknown.

  Receiving waters serve as a primary sink for the particulates associated with elevated metals.

  Sediment collected from bridge deck runoff can contain twice as high metal concentrations, as sediment which has first passed overland through vegetated ditches.

  Metal concentration in sediments showed close correlation with ADT on roads draining to receiving waters.

- **Biological** impacts were studied by bioassay experiments based on actual highway runoff. Algal assays found severe inhibition when exposed to 1, 5 and 10% of runoff from a highway, with very high ADT of 185,000, after two weeks of antecedent dry weather. However, runoff from 23,000 to 16,000 ADT in rural and suburban highways, with short antecedent dry days, was generally stimulatory to algal populations.

Bioassays with rainbow trout from highway runoff with ADT of 50,000 showed no toxic effects with filtered runoff, but unfiltered runoff was toxic with both a 50% dilution and with an undiluted sample. Similarly, runoff filtered through a 60 m grassy ditch was not toxic to the trout. Unlike the algal experiments, pollutants associated with particulates can be deleterious to rainbow trout.

Bioassays showed minimal acute toxicity of undiluted highway runoff for amphipod, isopod, water flea, mayfly and fathead minnows. Although decreases in abundance and diversity of benthic organisms has been attributed to urban runoff, these effects have not been shown for highway runoff. Similarly, urban runoff discharges have been implicated in accelerated entrophication of lakes, while highway runoff loadings by themselves have not shown these effects.

When salt concentrations in receiving waters exceed 1,000 mg/L chloride, it has been shown to increase the drift of benthic micro-invertebrates, decrease the biomass and diversity of algal species and increase the density of bacteria in streams.

The second part of the literature review deals with the various alternative measures available to mitigate the effect of pollutants. First the various planning, design and regulation measures, which could prevent some of the pollutants entering the highway system, are listed.

The next group of measures listed are applied after the pollutants are deposited, but before being washed off by runoff.

The last group of measures, which are the most common, deal with the pollution issues after the runoff has occurred.

A summary of the various water quality management measures are listed in Table 2.

Table 2/ Summary of highway runoff water quality management measures

Management Measure	POLLUTANT REMOVAL EFFECTIVENESS						
	Particulates	Heavy Metals	Pesticides PCBS	Organic litter Hydrocarbons	Nutrients	Pathogenic Bacteria	Overall Rating
1. Source Management Measures							
• Planning Measures	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Difficult to measure, probably moderate.
• Design and Operation	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Difficult to measure, probably moderate.
• Regulations: traffic, emission, inspection, litter, chemicals	High	High	High	High	High	High	Difficult to measure, probably high.
2. Post Deposition Measures							
• Street Cleaning and ditch maintenance	Low to Moderate	Low	Low	Low	Low	Low	Low
• Debris Removal, accident/spill Cleanup	Low to High	N/A	Low to High	Low to High	N/A	N/A	Moderate
3. Post Runoff Measures							
• Infiltration Systems	High	High	High	High	High	High	High
• Detention Basins - Wet	High	High	N/A	High	Moderate to High	Moderate to High	High
• Detention Basins - Dry	Low to High	Low to High	N/A	Low	Low	Low	Low
• Vegetative Controls							
- Grassed Channels	High	High	Moderate	High	High	High	High
- Filter Strips	High	High	Moderate	High	High to Moderate	High to Moderate	High
- Overland Flow	High	High	Moderate	High	High	High	High
• Wetlands	Low to High	High	N/A	Moderate to High	High	Moderate	High
• Catchbasins	Low	Low	Low	Moderate to Low	Low	Low	Low
• Filtration Systems	Moderate to Low	Low	Low	Moderate to Low	Low	Low	Low
• Flow Attenuation	Moderate	Low	Low	Low	Low	Low	Low

4/ Field Monitoring

4.1/ Description of Site

The second part of the project involved a series of field tests to study the relative effects of grassed or impervious solid surface channels on highway runoff quality.

The use of grassed drainage channels represents one of the low structurally-intensive measures for control of runoff quality. Grassed surfaces combine several beneficial effects which reduce the pollutant loads carried by runoff. There are three basic important phenomena contributing to this reduction of pollutant loads in runoff:

1) Reduction of the volume of runoff by infiltration through the grassed surface into soils;

2) Reduction in the flow velocity and therefore the runoff capacity to carry sediment;

3) Possible reductions in the pollutional character of runoff by contact with grass blades and the resulting uptake of chemicals by the grass.

The magnitude of beneficial effects of these processes differs and is not fully understood. It appears that the first two, infiltration and deposition of solids, are the most important.

The experiment can be designed and conducted in two ways: i) the so-called before-and-after-treatment design, or ii) the paired sites design. Each of these has some advantages and disadvantages.

In the before-and-after-treatment design, the monitoring of the site starts well before any control measures (i.e. piped median construction) are implemented, in order to establish the baseline data. Following the implementation of control measures, a new set of measurements is taken and the effects of control measures are obtained from comparisons of both sets of data. The main advantage of this approach is the fact that the measurements are taken at a single site. The main disadvantage is that the characterization of the before-and-after treatment conditions may require rather lengthy periods to collect adequate data for a whole range of climatic conditions. It should be recognized that the effectiveness of the control measures depends on the characteristics of storm events therefore, comparisons of the effects of controls on water quality have to be done for similar sets of events. The detection of trends in the data collected before and after treatment may take considerable time periods. Thus, this approach may not be workable under severe time constraints.

In the paired site approach, two sites with similar physical properties are selected and instrumented. One site is selected without any controls, i.e. open ditch, and the other site has control measures

implemented, i.e. piped median. Observations of runoff quality are then made simultaneously at both sites, for the same storm events, and the results are evaluated using the standard statistical tests for paired data. This approach is experimentally very powerful and expedient, because the whole group of independent experimental variables, related to the storm and antecedent condition characteristics, has been virtually eliminated in data comparisons. For this reason, the paired sites approach is generally preferred in non-point source studies and can produce evaluation results in relatively short time periods. This method has one possible disadvantage; some instrumentation needs to be duplicated. The key consideration is the proper selection of fully comparable paired catchments.

Considering the time constraints of this study, the paired site design was selected for the study.

The site selection for the two sites; grassed and paved median was based on the following criteria:

- grassed area to be at Dorchester swamp
- close distance between grassed and paved areas (<10 km)
- similar ADT, (>20,000 vehicles)
- similar pavements, type, age
- safe and easy access
- space availability for monitoring equipment
- representative runoff
- similar maintenance practices
- results should be available in time to adjust the proposed design layout for the Dorchester area widening, scheduled within the next three years

Following a review of potential sites, the two sites selected on Highway 401 were as follows:

- grassed section: Dorchester Swamp area watercourse No.3, near highway chainage 16 + 800, immediately west of Highway 73.
- Paved section, Highway 401 over Putnam Road.

Other sites, such as 401 at Speed River or Highway 8 near Highway 401, were rejected as non-representative sites.

The two sites are shown in Figure 1 - Location Plan.

The Dorchester site is located just west of Dorchester Road, Highway 73.

The four lanes are separated by a grassed median ditch (see Figure 2). Runoff in the grassed ditch from one eastbound and one westbound lane is collected by a catch basin at the centre of the ditch. Runoff

collected by the catch basin drops into the 1.83 x 1.52 m concrete culvert, which takes the flow into the small creek across the highway.

The two westbound lanes at the monitoring site were re-paved on September 26, 1989. Therefore, after that date, half of the runoff flowing into the ditch has originated from a newly paved asphalt surface.

During the summer of 1990, the grassed median was reduced from a width of approximately 4.5 m to 0.8 m by placing gravel next to the paved shoulder. Also a 1.5 m wide strip was paved along the inside shoulder of both eastbound and westbound lanes. One of the main purposes of the field monitoring and the selection of the Dorchester site was to establish the beneficial effect of grassed medians in reducing the concentration of pollutants. The drastic reduction in the grassed channel width jeopardized the integrity of the data set.

The Putnam Site monitoring facility collects runoff from a paved area, without flowing into a grassed channel. The site is located over the Putnam Road (County Road 30), where the overpass bridge contains only paved surfaces. East of the Putnam overpass, the grassed median collects runoff from one eastbound and one westbound lane.

The monitored flow is collected by a catch basin located along the eastbound lane, near chainage 23 + 000, on the south side of the highway, from one eastbound lane and from one acceleration lane. A 300 mm pipe discharges the runoff at the outlet, on the south side near the toe of the embankment. The estimated drainage area serving the test area catch basin is 510 m^2. As the flow expected at the site is far in excess of the container capacity (10 litres), a flow divider was fabricated. The incoming flow first enters a 1.25 x 0.8 m box lined with sheet metal, at a stilling chamber, then the flow is split, and a small percentage is passed through a narrow vertical slot, which diverts the flow into the sampling bottle. The rest of the flow is spilled. Adjustable boards permit the regulation of the percent of flow captured in the bottle.

By introducing the flow splitter, representative samples are collected through the duration of a particular storm event, rather than sampling only the initial flow.

Pavement condition reports prepared in 1988 for the westbound and eastbound lanes describe the following conditions:

Soil Type:	Huron clay loam and Guelph loam
Pavement:	150 mm granular A, plus 450 mm pit run granular placed 1.0 m beyond the pavement edge.

Maintenance:	Hot mix patching, cold mix to transverse and longitudinal cracks and joints and in wheel tracks.
Performance:	Fairly good, with the side slightly rough due to the bumps at the transverse joints. Full transverse cracking is moderate with depressions at most that vary 75 - 150 mm in width. Slight - moderate ravelling at centreline, slight wheel track rutting, longitudinal wheel track and centreline cracks occur intermittently. There are several uneven or rough areas to the outside edge that result in a slightly poorer ride.
AADT (1988):	Dorchester site = 31,700 Putnam Thru lanes = 31,000 WBL off ramp = 320 EBL on ramp = 248
Sand and Salt Usage:	Allowable application rates, Sand - 570 kg/2-lane km Salt - 130 to 170 kg/2-lane km

4.2/ Monitoring Program

For runoff monitoring, the approach based on *event mean concentrations* (EMCs) was adopted. In this approach, the emphasis is placed on measuring the mean concentrations for individual events, rather than trying to establish variations in instantaneous concentrations during runoff events. The advantages of the EMC approach are numerous and the use of this approach can be justified by the receiving water quality considerations. The existing water quality criteria are generally based on bioassay studies in which biota is exposed to various levels of contaminant concentrations over extended time periods. Consequently, the response of biota to varying instantaneous concentrations is little known. For typical storms, the duration is in the range of from four to eight hours and this time scale compares well to the bioassay time scales.

EMCs also can be better analyzed for any cause and effect relationships, because they exhibit much smaller variability than instantaneous concentrations. By eliminating the background noise demonstrated by instantaneous concentrations, the probability of discovering any existing relationships between the experimental variables increases. Finally, the approach based on EMCs reduces the study costs - the corresponding instrumentation often can be simplified by directly collecting flow-proportional samples and the number of samples to be analyzed is dramatically reduced - one per storm event. Consequently, the analytical costs are greatly reduced.

Composite samples were collected and shipped to Dillon Laboratory located in Mississauga. Altogether eight composite samples were taken, four of each at the two sites between November 1989 and December 1990. A summary of the results is shown in Table 3.

Table 3/ Highway 401 runoff water quality

Parameter	Dorchester Road (grassed)					Putnam Road (paved)					Relative Concentrations Grass over Concrete H–higher, L–lower S–same		
Sample No.	0002	0011	0022	0032	average	0001	0012	0021	0031	average			
Date of Sampling	15/11/89	14/06/90	09/10/90	18/12/90		15/11/89	14/06/90	09/10/90	18/12/90				
pH	7.9	7.6	7.9	7.5	7.7	7.3	6.7	7.1	7.0	7.1	L	L	L
Conductivity	320	300	293	3870	1196	150	150	135	1910	586	H	H	H
Total Suspended Solids	56	26	55	40	44	210	5	15	70	75	L	H	H
BOD	3195	5	27		1076	3315	7	15		1112	L	L	H
COD	39	32	55		42	23	20	59		34	H	H	S
NH3–N, Total	0.28	0.5	0.20	0.10	0.08	0.49	0.50	0.50	0.50	0.50	L	S	L
TKN–N	1.83	1.80	1.00	0.80	1.4	0.74	1.20	1.10	1.30	1.10	H	H	S
Total Phosphorus	–	0.21	0.86	0.12	0.3	–	0.07	2.10	1.61	1.26	–	H	L
Phosphate (PO_4 3–)	<0.05	0.30	0.14	0.06	0.1	<0.05	2.30	6.40	1.80	2.60	S	L	L
Nitrite (NO_2–),as N	<0.02	0.07	0.01	<0.5	0.09	<0.02	0.05	0.06	<0.1	0.04	S	S	L
Nitrate (NO_3–),as N	3.80	1.37	1.37	2.20	2.2	<0.01	0.87	0.68	1.26	0.71	H	H	H
Calcium (Ca)	35.8	72.4	50.7	208.0	91.7	36.2	14.8	20.7	32.6	26.1	S	H	H
Magnesium (Mg)	3.75	10.80	4.87	23.30	10.6	5.61	0.98	1.64	2.77	2.75	L	H	H
Sodium (Na),dissolved	20.4	9.9	6.5	880.0	229.2	11.0	9.6	7.0	411.0	110.0	H	S	S
Bromide (Br–)	<0.05	<0.05	<0.05	<0.5	<.16	<0.05	<0.05	<0.05	0.06	<0.05	S	S	S
Chloride (Cl–)	8.0	10.3	6.1	1750.0	443.6	9.8	14.0	9.3	636.0	167.3	L	L	L
Fluoride (F–)	2.4	0.14	0.16	<3	1.05	3.00	0.15	0.12	<1	1.10	L	S	H
Sulphate (SO_4 2–)	12.8	18.2	18.8	46.0	24.0	9.7	13.4	17.9	52.0	23.3	H	H	H
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	S	S	S
Cobalt (Co)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	S	S	S
Copper (Cu)	0.03	0.02	0.02	0.01	0.02	0.03	0.01	0.02	0.04	0.03	S	S	S
Iron (Fe)	1.72	3.78	0.15	0.87	1.63	3.29	0.26	1.24	3.02	2.00	L	H	L
Manganese (Mn)	0.07	0.18	<0.01	0.03	0.07	0.14	0.05	0.07	0.16	0.11	L	H	L
Nickel (Ni)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	S	S	S
Phosphorus (P)	0.38	0.24	0.14	0.11	0.22	0.91	0.69	1.93	0.98	1.10	L	L	L
Lead (Pb)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	S	S	S
Zinc (Zn)	0.04	0.04	0.01	0.04	0.03	0.56	0.44	0.25	0.93	0.55	L	L	L
Total Cyanide	0.005	0.007	<0.001	0.003	0.0038	0.003	0.006	0.004	0.005	0.005	H	H	L
Total Plate Count (/mL)	2750	25000	5000	290	3200	4400	30000	8000	340	4800	L	L	L
Total Coliform (/100mL)	48	100	600	20	90	480	500	800	40	300	L	L	L
Total Fecal Coliforms (/100 mL)	22	16	<1	<1	4	40	300	<1	<1	10	L	L	S
Fecal Streptococci (/100mL)	80	<1	<1	<1	3	132	<1	<1	<1	4	L	S	S
Organochlorine Pesticides (ug/L) (20 parameters)	–	–	ND			–	–	ND			–	–	S
Polycyclic Aromatic Hydrocarbons (ug/L) (16 parameters)	–	–	ND			–	–	TR for 8 of 16			–	–	S
Phenoxyacid Herbicides (ug/L) (3 parameters)	–	–	ND			–	–	ND			–	–	S
Base/Neutral Extractable Organics (ug/L) (28 parameters)													
– bis(2–chloroethyl) ether	–	–	ND			–	–	0.20			–	–	L
– bis(2–ethylhexyl) phthalate	–	–	TR			–	–	0.75			–	–	L
– di–n–octyl phthalate	–	–	ND			–	–	TR			–	–	L
– remaining 25 analysed	–	–	ND			–	–	ND			–	–	L

NOTES:

ND – Not Detected

TR – Trace Amount

"Averages computed with " < " values were done by either:

a: using half the detection limit when most values were detected

b: using the stated values when most values were " < "

Averages for bacterial parameters are geometric means.

The relative concentration columns compare for each date the grassed data data with the paved site. For example on the 14/06/90 the Dorchester sample conductivity (300) was higher than the Putman value(150). In the case of pH, a lower number indicates a higher value.

A comparison of the Dorchester (grassed) and Putnam (paved) runoff quality (average values), indicates the following:

Parameters tending to have higher concentrations in grassed runoff were: Hydrogen ion (pH), conductivity, COD, TKN-N, Nitrate, Ca, Mg, Na, Cl. In these samples the largest differences in the parameters of grass over concrete runoff were the Nitrate, Ca, Mg, Cl, but the ratio of the averages did not exceed four. As expected, the chloride concentrations increased considerably in the winter sample, collected after the application of salt on the highway. The chloride concentration range of 6-14mg/L increased to 1750 mg/L at the Dorchester site and 636 mg/L at the Putnam site.

When comparing the samples with water quality objectives presented in Table 4, or with the MOE storm sewer discharges by-law presented in Appendix A, the use of the objectives recommended for the protection of aquatic habitat appears to be the most practical approach. Table 5 compares the averages of the four samples with these objectives.

A review of water quality samples was conducted with a biology perspective. It was found that on average, water quality parameters sampled in the grassed area were lower 63% of the time than those in the paved area (Table 3). While this may be a subjective observation not applicable to statistical methods, looking at selected values in detail expands on the position that the grassed swales can afford a reasonable level of protection to the receiving waters.

The hydrogen ion concentrations of the waters at Putnam Road (paved) were higher (i.e. lower pH) than at Dorchester Road (grassed). On the logarithmic scale, each 1.0 change in pH corresponds to a 10-fold change in hydrogen ion concentration. Therefore, a difference of 0.9 units (example: 14/08/90, Table 3) represents an 8-fold change. The concentration values listed in Table 3 are for the sum of un-ionized ammonia and ammonium, ie. they are for total ammonia. The percentage of un-ionized ammonia present is controlled by the pH and temperature of the water. It is the un-ionized ammonia portion of the total ammonia reported that is compound toxic to aquatic organisms.

The MOE Blue-book recommends that concentrations of un-ionized ammonia should not exceed 0.02 mg/L for the protection of aquatic life. Considering this information with the reported pH values, total ammonia (NH_3-N) concentrations and temperatures, the data obtained (see results of Table 5) indicate ammonia is not a concern.

It is unlikely that un-ionized ammonia will be toxic to aquatic organisms at lower temperatures (Boyd, 1979) in areas where the receiving waters are below pH 8.0. The pH of waters generally follow the characteristics of the bedrock and soils they flow over. In areas of sedimentary rock or clayey soils,

Table 4/ Water quality objectives, guidelines and regulations

	1	2	3	4	5	6	7
Parameter	**Protection of Aquatic Habitat**	**Agricultural Uses**	**Ontario (MOE, 1983)**	**(H&WC, 1989)**	**United States (Pontius, 1990)**	**World Health Organization (WHO, 1984)**	**Dorchester-Putnam Average**
COLLECTIVE DESCRIPTORS (mg/L)							
Hardness (as $CaCO^3$)			(80-500)	(80-500)		(500)	
Alkalinity (as $CaCO^3$)			(30-500)				
Total Dissolved Solids (TDS)			(500)	(500)	(500[5])	(1,000)	
Total Organic Carbon (TOC)			(5.0)				
pH	6.5 - 8.5		(6.5 - 8.5)	(6.5 - 8.5)	(6.5 - 8.5)	(6.5 - 8.5)	7.7 - 7.1
Dissolved Oxygen	4 - 8						
MAJOR CATIONS (mg/L)							
Sodium (Na)			20	(200)	none[1]	(200)	229-110
Magnesium							10.6 - 2.7
Calcium (Ca)							91.7 - 28.1
MAJOR ANIONS (mg/L)							
Fluoride (F)		2.0	1.0 - 1.4, 2.4	1.5	4	1.5	1.05 - 1.10
Chloride (Cl)			(250)	(250)	(250)	(250)	443 - 167
Nitrate (as N)		100[4]	10	10	10	10	
Sulphate (SO_4)			(500)	(500)	(250)	(400)	24 - 23.3
NUTRIENTS (mg/L)							
Ammonia (as NH_3)	0.02						
Organic Nitrogen (as TKN - NH_3)			(0.15)				
Total Phosphorous	0.01 - 0.03						0.3 - 1.26
Nitrite (as N)		10	1.0	1.0			.09 - .06

1,2 *Ontario MOE, 1984. Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, May 1984 Revision.*

3. *Ontario MOE, 1983. Ontario Drinking Water Objectives.*

4. *Health and Welfare Canada, 1989. Guidelines for Canadian Drinking Water Quality. Fourth Edition.*

5. *Pontious, F.W. 1990. Complying with the New Drinking Water Quality Regulations. Journal of the American Water Quality Regulations, Volume 82, pp.32-52.*

6. *World Health Organization, 1984. Guidelines for Drinking Water Quality, Volume I, Geneva.*

( ) Numbers in brackets refer to aesthetic objectives.

Table 4/ Water quality objectives, guidelines and regulations (continued)

	1	2	3	4	5	6	7
Parameter	Protection of Aquatic Habitat	Agricultural Uses	Ontario (MOE, 1983)	(H&WC, 1989)	United States (Pontius, 1990)	World Health Organization (WHO, 1984)	Dorchester-Putnam Averages
TRACE CONSTITUENTS (ug/L)							
Silver (Ag)	0.0001		0.05		0.05		
Aluminum (Al)	0.1	5.0	(0.1)		0.05[2]	(0.2)	
Arsenic (As)	0.1	0.2	0.05	0.05	0.05, (0.09[2])	0.05	
Beryllium (Be)	0.011 - 1.1						
Cadmium (Cd)	0.0002	0.05	0.005	0.005	0.01	0.005	<0.01
Chromium (Cr)	0.1	1.0	0.05	0.05	0.05	0.05	
Copper (Cu)	0.005	0.5	(1.0)	(1.0)	(1.0)	(1.0)	.02 - .03
Iron (Fe)	0.3		(0.3)	(0.3)	(0.3)	(0.3)	1.83 - 2.0
Manganese (Mn)			(0.05)	(0.05)	(0.05)	(0.1)	.07 - 0.11
Lead (Pb)	0.005 - 0.025	0.1	0.01	0.05	0.05	0.05	<0.05
Nickel (Ni)	0.025	1.0					<0.05
Selenium (Se)	0.1	0.05	0.01	0.01	0.01	0.01	
Vanadium		1.0					
Zinc (Zn)	0.03	25.0	(5.0)	(5)	(5)	(5.0)	0.03 - 0.55
Mercury (Hg)	0.0002		0.001	0.001	0.002	0.001	
Phenols	0.001		(0.002)				
Cyanide (CN)	0.005		0.2	0.2		0.1	.0038 - .005

1,2 *Ontario MOE, 1984. Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment, May 1984 Revision.*

3. *Ontario MOE, 1983. Ontario Drinking Water Objectives.*

4. *Health and Welfare Canada, 1989. Guidelines for Canadian Drinking Water Quality. Fourth Edition.*

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6. *World Health Organization, 1984. Guidelines for Drinking Water Quality, Volume I, Geneva.*

( ) Numbers in brackets refer to aesthetic objectives.

Table 5/ Comparison of samples with water quality objectives

Parameter	Objective*	Grassed[1]	Paved[1]
pH	6.5 - 8.5	7.7	7.1
Cadmium	0.0002	<0.01	0.01
Copper	0.005	0.02	0.03
Iron	0.3	1.63	2.0
Lead	0.005 - 0.025	<0.05	0.05
Nickel	0.025	<0.05	0.05
Zinc	0.03	0.03	0.55
Cyanide	0.005	0.004	0.005
Dissolved Oxygen	4-8		
Ammonia	0.02	<0.003	0.001
Total Phosphorus	0.01-0.03	0.30	1.26

[1] Averages of four samples

* For the protection of aquatic habitat.

water will have high pH values and correspondingly higher concentrations of toxic un-ionized ammonia.

Phosphate (PO_4^{-3}) concentrations in the grassed area runoff were significantly lower than that in the paved area runoff (Table 3). Presumably the plants in the grassed area are phosphorus deficient and readily take up the available PO_4^{-3}. Concentrations recorded (Table 3) from the paved area are excessively high and discharge could likely cause nuisance algae and aquatic weed growth downstream (Wetzel, 1975). This nuisance plant growth is particularly destructive to sensitive aquatic habitats because the increased photosynthetic activity reduces night time oxygen levels and increases CO_2 levels, which could cause wide fluctuations in the pH of poorly buffered water (Boyd, 1979). MOE provides guidelines on the levels of total phosphorus to avoid nuisance plant growth. To compare concentrations to the total phosphorous guidelines, divide phosphate values by three.

The MOE Blue-book indicates that excessive plant growth in rivers and streams should be eliminated at a Total Phosphorous concentration below 0.03 mg/L. From a biological productivity perspective, inorganic orthophosphate (PO_4^{-3}), is the only form of phosphorous of significance (Wetzel, 1975). The other form of phosphorous in water is principally organic phosphorous bound to solid particles and, as such, it is biologically unavailable in the water column (Stechey and Trudell, 1990). As phosphate is apparently removed by the grassed areas, it may be appropriate to maintain these as protection from nuisance algal growth in the receiving waters.

For the winter sample, chloride concentrations were high in both paved and grassed medians, with the higher value in the grassed area. The other data show concentrations of chloride in the grassed area slightly lower than the paved area.

Variations in sodium concentrations are similar to chloride. Calcium and magnesium are usually higher on the grassed area but are not toxic to aquatic organisms. Manganese and iron are found in various concentrations at the two sites but also are not components believed to be toxic to aquatic organisms. Iron concentrations exceed the Blue-book water quality objectives.

With respect to zinc toxicity to fish, two competing mechanisms appear to operate as the pH rises, dissolved zinc becomes increasingly toxic, but at higher pH levels (> 8.5) it is replaced by zinc precipitate, which is of low toxicity to fish (Bradley and Sprague, 1985). Acute toxicity of zinc to Rainbow Trout occurs at around 0.55 mg/L zinc sulphate (Bradley and Sprague, 1985). Fathead Minnow are sensitive to low concentrations of zinc. The maximum acceptable toxicant concentration (MATC) for Fathead Minnow is 30-180ug/L (0.03 - 0.18 mg/L) (Murty, 1986). The toxicity of zinc to bluegills (Pickering, 1968) increases as the dissolved oxygen concentration decreases. Our results indicate

significant differences between zinc concentrations between sampling sites. Runoff from grassed areas have zinc concentrations within the MATC for Fathead Minnow, while the values from the paved area far exceed the MATC's (Table 3) and exceed acute toxicity levels for Rainbow Trout. The MOE Blue - book suggests a maximum of 0.03 mg/L to protect aquatic life, compared to the paved area concentration of 0.25 - 0.93 mg/L.

Other heavy metals were not found to be significantly different between sampling locations.

Bacteriological studies (Total Plate Count, etc.) indicate that the grassed areas have lower values than those found near the paved location. High bacterial counts, such as found here, are most important where the receiving waters are to be used for drinking water, livestock watering or body-contact sports. To aquatic organisms, they represent a negligible effect.

Water temperature in the receiving water body plays a large role in determining the suitability of a stream for aquatic habitat, as the toxicity or availability of compounds and elements is temperature dependent (Murty, 1986). Dissolved oxygen concentration in water increases with decreasing temperature, while ammonium toxicity increases with increasing temperature.

Temperature also regulates the speed of the bacterial process of converting ammonium to toxic nitrite and non-toxic nitrate. Nitrate is the final product of this reaction and is generally utilized by aquatic plants as a source of readily available nitrogen. No significant difference was detected in the nitrite concentrations of the two sites, but on all occasions, the nitrate concentrations were significantly higher in the grassed area runoff (Table 3). This level of nitrate discharge may cause excessive algae and nuisance weed growth in the receiving waters, although this process is usually limited by the phosphate available.

In conclusion, the range of parameters, both in the grassed and paved runoff, was similar to those reported in the literature, as shown in Table 6.

There was insufficient data collected at the Dorchester site before and after the reduction of the grassed channel to detect any changes in the water quality.

The original study objective was to collect more than eight composite samples to compare the runoff quality at the paved and grassed median. In view of the alteration to the grassed median, which resulted in the reduction of the width of the grassed channel from 4.5 m to 0.8 m, and the fact that the results obtained from the two sites were well within the range identified by the literature, it was decided to terminate the field program in December 1990.

Table 6/ Summary of U.S. highway runoff composite quality data and Highway 401 data - mg/l

Parameter	U.S. Pollutant Concentration (mg/L)		Highway 401 Data	
	Minimum	Maximum	Minimum	Maximum
pH	4.90	7.95	7.0	7.9
TS	68	57,400	5	210
VTS	10	510	-	-
SS	6	2,160	-	-
VSS	4	317	-	-
Pb	ND	6.30	<0.05	<0.05
Zn	0.036	2.90	0.01	0.93
Fe	0.30	115	0.15	3.78
Cr	ND	0.19	-	-
Cu	ND	0.59	0.01	0.04
Cd	ND	0.06	<0.01	<0.01
Ni	ND	0.22	<0.05	<0.05
Hg	ND	0.001	-	-
As	ND	0.03	-	-
Na	2.1	22,500	6.5	880
Ca	4.0	450	14.8	208
Cl	2.0	35,000	6.1	1,750
Oil and Grease	1	21	-	-
PO_4-P	0.03	4.45	<0.016*	2.10*
TKN	ND	9.80	0.74	1.83
NO_2+NO_3	ND	9.00	-	-
TOC	4	182	-	-
COD	16	660	20	59
SO_4	ND	180	9.7	52

Notes:

ND = Not Detectable.
** Computed from PO_4 data, by dividing the results by 3.06.*
pH is not measured as mg/l

The U.S. Pollutant Concentration data was obtained from Kobriger, N., and Geinepolos, A. (1984), and represent observations taken at sites which have higher ADT values than those recorded at the Highway 401 sites.

4.3/ Expected Water Quality at the Dorchester Site

MTO is proceeding with plans to improve safety conditions on Highway 401 by paving the median to install a continuous median barrier.

As predicted by the limited sampling taken at the site and at the Putnam area, the most significant change in concentration expected in the water quality at the Dorchester site, after the reconstruction, will be the increase of zinc, ammonia and total phosphorus concentrations in the runoff. If the concentration values observed at the Putnam site for the above three contaminants are typical for the all-paved median arrangement, the change in the concentration may be an order of magnitude larger.

The stormwater from the highway at the Dorchester monitoring site enters the creek through a catch basin at the median. The diluted highway runoff then flows under the two lanes, before entering the Dorchester swamp, a Class 1 wetland. The combined flow then moves from the highway to Dorchester Mill Pond.

The effect of dilution in a similar watercourse originating near the west end of the Dorchester Swamp and also outletting at the Dorchester Mill Pond was measured by the Upper Thames Conservation Authority, when testing for chloride. A concentration of 1,560 mg/L at the edge of the highway decreased to 8.5 mg/L near the mouth of the Mill Pond.

Similar effects can be expected for the zinc concentration. It is recommended that after the highway is reconstructed, samples of the storm runoff should be taken at the highway and downstream at the Mill Pond, during low flow conditions, to determine the dilution effect downstream.

No significant changes are expected in the chloride levels after the reconstruction as the very limited data collected showed concentrations in the grassed median higher than the Putnam site. As the new paved median will not be a driving lane, it should not result in additional application of salt in winter.

Generally, the water quality of the runoff after the reconstruction of the Dorchester area will be within the range of data recorded at the two sites. An increase can be expected in the concentration of NH_3-N, total phosphorus, phosphate, copper, iron, manganese, phosphorus, zinc, total cyanide, and in the total plate coliform, and total coliform counts, when compared to the existing data collected at Dorchester site. However, the data base collected is rather small to derive any firm conclusions or predict increases in concentration.

5/ Conclusions and Recommendations

5.1/ Conclusions

The present study, which can be regarded as an initial activity in the stormwater quality management policy formulation, identified the available literature and found that the limited samples collected at the two Highway 401 locations parallel the data described in the literature.

A review of the literature confirmed that a highway system is a source of pollutants. The effect of these pollutants on the environment is a concern to highway agencies and other parties interested in the protection of the environment.

There is a lack of data in Ontario on the parameters of highway pollutants, their make-up and concentration. The only stormwater quality information available in Ontario pertains to urban runoff, which, according to the literature, can exhibit similar characteristics to the quality of highway runoff.

MTO has adopted the following highway drainage objectives for runoff quantity policy:

- to maintain and promote good management of provincial highway drainage systems;
- to assure that prudent decisions are made before using the highway right-of-way for detention of runoff; and
- to minimize impacts to the provincial highway system as a result of runoff from upstream developments.

MTO has also implemented policies and procedures related to water quality protection. These include erosion and sediment control during construction, spills response policy, and de-icing chemical research. In addition, MTO will continue to address the control of highway stormwater runoff quantity and quality, as provincial policies are developed. Project specific issues are addressed as part of the Environmental Assessment process applied to provincial highways.

Generally, the literature identified good correlation between the average daily traffic (ADT) and pollutant loading.

At present, there is insufficient field monitoring data available in the literature to obtain a close correlation between pollutant characteristics and land use, pavement type, type of highway drainage or upstream non-highway uses and facilities.

As expected, there is a wide range of concentration in the data collected at the various European and North American monitoring sites. This is not surprising when there are so many factors which can influence the highway runoff quantity and quality.

Unfortunately, very little is present in the literature on the downstream effects of water quality parameters from highway runoff.

The eight samples collected and analyzed during the study fell within the range of pollutant concentrations reported in the literature. The cadmium, copper, iron, lead and nickel concentrations in the samples generally did not meet the objectives used for the protection of aquatic habitat.

The integrity of the grass channel was seriously affected during the early part in the field program, after the reduction of the grassed median from 4.5 m to 0.8 m. Although one of the main purposes of the study was to compare the effects of grassed and paved median, it could not be totally addressed.

The limited data collected at the two sites indicate that some parameters, such as hydrogen ion, conductivity, total Kjeldahl nitrogen, nitrite, nitrate, calcium, magnesium, and chloride appear to be at higher concentration in grassed runoff than in the paved runoff.

When compared to the MOE (1984) objectives used for the protection of aquatic habitat, the copper, iron, zinc, ammonia and total phosphorus average concentrations exceeded the objectives. However, there was insufficient data collected at the Dorchester site to determine the effects of a grassed channel on the quality of runoff. Nevertheless, it is interesting to note that, even after a significant reduction in the grassed channel width, the remaining grassed channel continued to produce consistently higher concentration values for a number of parameters, and consistently lower values for others.

It is difficult to categorize which of the contaminants are highly toxic, less toxic, or leave limited effect, as it varies with the species affected, or the concentration in the runoff and dilution in the receiving system.

Another important aspect of the monitoring program was to identify the possible effect of a paved median replacing a grassed channel at the Dorchester site. If the concentration values observed at the Putnam site are typical for paved medians, an increase in zinc, ammonia and total phosphorus concentration can be expected at Dorchester after reconstruction. However, the data base collected at the two sites is too small to derive firm conclusions on the differences in the water quality in grassed and paved medians, or to provide a reasonable estimate of the changes expected at the Dorchester site, after the median changed from grassed to paved.

5.2/ Recommendations

It is recommended that the MTO should continue their long-term program to develop a highway stormwater quality policy. To provide the necessary data base and supporting information, additional data collection and research on the composition of highway runoff quality and its effect on the receiving system is needed.

MTO should proceed with a computer model selection follow-up study. The purpose of such a study would be to evaluate a computer model that could be used under Ontario conditions, which would assist designers and planners to estimate the expected quantity and quality of highway runoff until additional data is available. The selected model would be calibrated, using the limited samples collected at the two Highway 401 sites and at the QEW Burlington monitoring sites and from additional data collected during future research work as recommended.

If the sampling program is continued at the Dorchester site at a future date, it can provide a comparison between the pre- and post-construction runoff quality and, at the same time, can provide first-hand evidence on the decrease in storm runoff concentration reaching the swamp.

Based on the limited data and the literature review, it appears that the water quality in highway runoff can be degraded, particularly from highways with very high ADT values. The downstream impacts of the highway runoff is extremely difficult to predict or to quantify. Consequently, it is equally difficult to make any practical recommendation on the need for protection or on the selection of appropriate measures to reduce the concentration and loading in highway runoff. The concern regarding the need to provide protection to the environment from the potential effects of runoff quality becomes more important where the receiving watercourse is classified as a potentially sensitive one due to the following uses: water supply, cold water fishery, or body contact recreation.

Based on the limited sampling and the literature review, the water quality in the receiving watercourse at the Dorchester site will not change substantially after the reconstruction of the median. However, the same watercourse discharges into the Dorchester Swamp and to the existing Mill Pond located further downstream. This area could be very sensitive to any changes to the local environment, as the receiving watercourse is a coldwater stream which is undergoing a fish rehabilitation program, and the local shallow aquifer is used as a source for municipal water supply.

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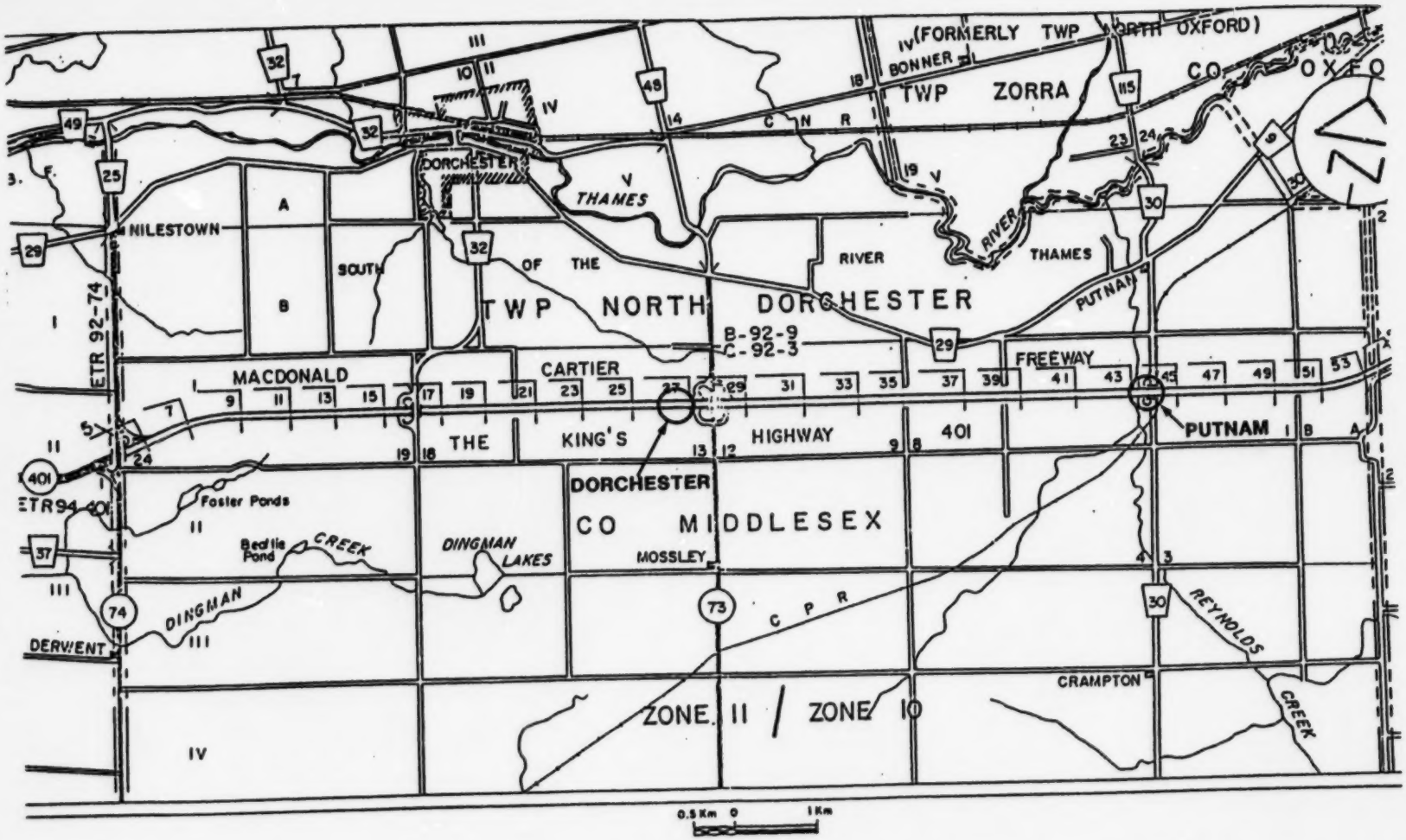
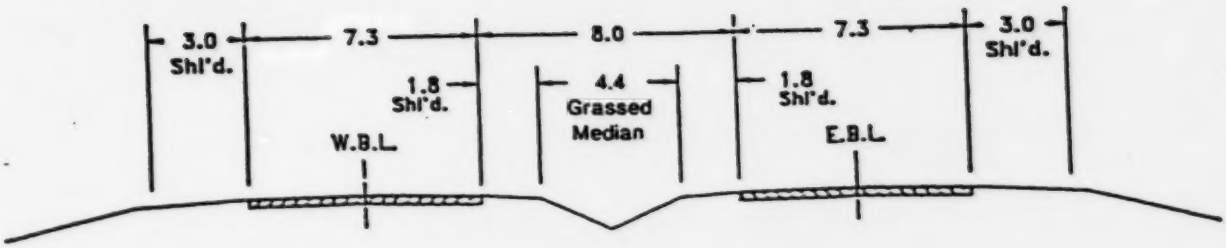
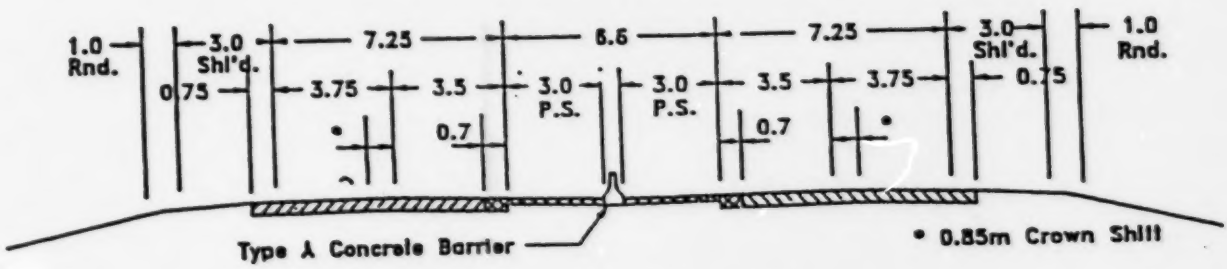


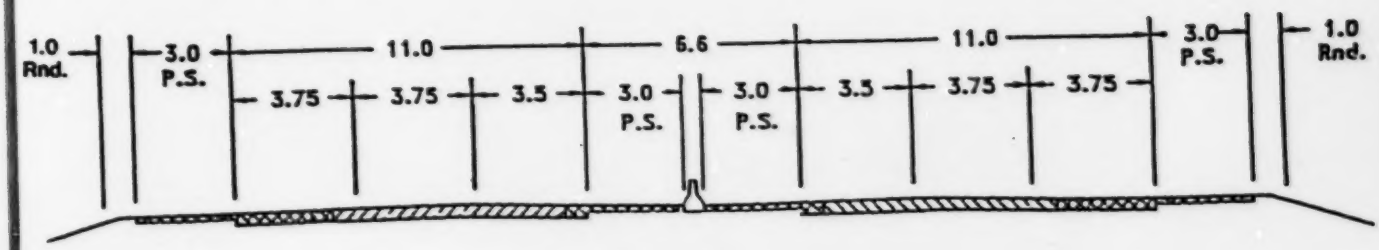
Figure 1 / Location Plan



EXISTING SECTION



PROPOSED 4–LANE SECTION



ULTIMATE 6–LANE SECTION

Figure 2 / Highway Sections

ISBN 0-7729-4419-9

Appendix A / Model Sewer Use By-Law

- A Model By-Law to Control Waste Discharges to Municipal Sewers
- Sewer Use Model By-Law Appendix/Guidance Manual
- Compendium of Public Comments on Model Sewer Use By-Law and Ministry Responses

AUGUST 1988

Environment Ontario

Jim Bradley
Minister

SECTION 3

DISCHARGES TO STORM SEWERS

3(1) No person shall discharge or deposit or cause or permit the discharge or deposit of matter of a kind listed below into or in land drainage works, private branch drains or connections to any storm sewer,

1. matter of any type or at any temperature or in any quantity which may:

   (a) interfere with the proper operation of a storm sewer;

   (b) obstruct a storm sewer or the flow therein;

   (c) result in a hazard to any person, animal, property or vegetation;

   (d) impair the quality of the water in any well, lake, river, pond, spring, stream, reservoir or other water or watercourse; or

   (e) result in the contravention of an approval, requirement, direction or other order under the Ontario Water Resources Act or the Environmental Protection Act (Ontario) with respect to the storm sewer or its discharge; and

2. without limiting the generality of the foregoing, any of the following:

   (a) water at a temperature greater than 40° Celsius;

   (b) water having a pH less than 6.0 or greater than 9.0;

   (c) water containing more than 15 milligrams per litre of suspended solids;

   (d) water containing dyes or colouring material which discolour the water;

   (e) water containing solvent extractable matter of animal or vegetable origin or of mineral or synthetic origin which causes a visible film, sheen or discolouration on the water surface;

   (f) water containing any of the following in excess of the indicated concentrations:

200 micrograms/litre
Chromium expressed as Cr

50 micrograms/litre

Zinc expressed as Zn
Lead expressed as Pb
Nickel expressed as Ni

10 micrograms/litre

Copper expressed as Cu

1 microgram/litre

Cadmium expressed as Cd
Mercury expressed as Hg

200 per 100 millilitres

Fecal coliforms

(g) the following matter in any amount:

Sewage
Once-through cooling water
Blowdown

(h) the following materials in any amount:

Automotive or Machine Oils and Greases
Fuels
Paints and Organic Solvents
PCBs
Pesticides
Severely Toxic Materials
Waste Disposal Site Leachate
Waste Radioactive Materials

(i) the following hazardous wastes in any amount:

Acute Hazardous Waste Chemicals
Hazardous Industrial Wastes
Hazardous Waste Chemicals
Ignitable Wastes
Pathological Wastes
PCB Wastes
Reactive Wastes

3(2) Subclause 3(1) 2.(g) does not apply to prevent the discharge of once-through cooling water or blowdown when,

(a) the once-through cooling water or blowdown is being discharged pursuant to a certificate of approval or order relating to the premises under the Environmental Protection Act (Ontario) or the Ontario Water Resources Act which expressly allows the discharge;

(b) the owner or operator of the premises has written approval from the municipality which expressly authorizes the discharge from the premises; and